VOL. XLII JANUARY 1958 NO. 1

THE JOURNAL OF AGRICULTURE

of the

UNIVERSITY OF PUERTO RICO

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EFFECT OF LIME AND PHOSPHATE-BEARING MATERIALS ON SUGAR-CANE YIELDS
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PUBLISHED BY
UNIVERSITY OF PUERTO RICO
AGRICULTURAL EXPERIMENT STATION
RIO PIEDRAS, P. R.

Entered as second-class matter June 1, 1953, at the post office at Río Piedras, under the Act of August 24, 1912, as amended by the Act of August 4, 1947.

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(*Continued on inside back cover*)

THE JOURNAL OF AGRICULTURE
OF THE UNIVERSITY OF PUERTO RICO

Issued quarterly by the Agricultural Experiment Station of the University of Puerto Rico, for the publication of articles by members of its personnel, or others, dealing with any of the more technical aspects of scientific agriculture in Puerto Rico or the Caribbean Area.

Vol. XLII January 1958 No. 1

Effect of Lime and Phosphate-bearing Materials on Sugarcane Yields

J. A. Bonnet, M. A. Lugo-López, J. Roldán, and R. Pérez-Escolar[1]

INTRODUCTION

May (*6*)[2], in 1910, obtained yield responses for a plant and a first-ratoon crop of sugarcane when lime and fertilizer were applied to a heavy clay soil in the Mayagüez area. Similar responses were reported in 1914 by Gile and Ageton (*4*) in a Catalina clay in the Añasco area. Pietri and Gómez-Montoya (*8*) obtained increases of sugarcane yields when lime was applied to a Coloso clay up to an amount equivalent to 80 percent of the soil base saturation. No additional responses were obtained by saturating with lime up to 100 percent.

The use of phosphatic fertilizers for sugarcane grown in coastal plain soils has been seriously questioned (*1*). In many instances their application has not exerted any effect, either beneficial or detrimental, on the yields of several successive sugarcane crops. The question has been raised as to whether the same situation would hold on other acid humid-region soils where sugarcane is grown in Puerto Rico, outside of the coastal plain area.

This paper reports data obtained from a field experiment designed to determine both the effect on sugarcane yields of lime and of two sources of phosphorus added to an acid soil of Puerto Rico.

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Appreciation is expressed to the following staff members who helped at one time or another with field and laboratory work: H. Gandía, Associate Horticulturist, formerly in charge of the Corozal Substation: R. Olivencia, formerly Research Assistant in Agronomy; A. R. Riera, Associate Chemist in Charge of the Central Analytical Laboratory; G. Malaret Juarbe and G. García Monge, Research Assistants in Chemistry; C. I. Alsina, Analytical Chemist; and E. J. Brenes, Assistant Soil Scientist. Thanks are also expressed to Companie Nord Africaine de L'Hyperphosphate Reno, 47 Rue de Liege, Paris, France, and to their agent, M. Bernard Carreau, Fort de France, Martinique, for supplying the hyperphosphate.

[2] Italic numbers in parentheses refer to Literature Cited, p. 6.

MATERIALS AND METHODS

The experiment was located at the Corozal Agricultural Experiment Substation Farm in the interior, humid region of Puerto Rico. The soil is a nearly level Lares clay, an acid, medium-friable, Red and Yellow Podzolic (*9*) soil, occurring in terrace formations and derived from materials washed from the Lower Tertiary clays and shales. Feldspars are absent in the soil and kaolinite is the predominant clay mineral (*5*).

The experiment consisted of a split-plot design with a total of 16 treatments. The main treatments were the two sources of phosphorus: superphosphate and hyperphosphate,[3] and the lime application. The subtreatments were the different rates of phosphorus applied. The subtreatments consisted of four different rates of application: 0, 50, 125, and 200 pounds of P_2O_5 to the acre. Both the main treatments and subtreatments were completely randomized and the subtreatments were replicated six times for a total of 96 plots, each 24 x 16 feet. On August 22, 1952 half of the plots received lime at the rate of 4 tons to the acre. The original pH of the topsoil was 5.6 while that of the reddish subsoil was 4.0. The field was planted on July 30–31, 1952, to sugarcane variety P.R. 1000. Six rows, 16 feet long, were planted at a 4-foot interval. One unplanted row was left between the sugarcane rows to separate the plots. On September 5 all plots received ammonium sulfate and muriate of potash at rates of 1,000 and 125 pounds to the acre, respectively. The plant crop was harvested February 1–2, 1954. The two succeeding ratoon crops were fertilized in a similar way to the plant crop, including the differential phosphorus treatments, but the lime application was not repeated. The first ratoon was harvested February 14–16, 1955, and the second March 5–6, 1956.

Soil samples were taken on April 10, 1956, 44 months after the lime was applied. Soil pH was determined with a Macbeth pH-meter. In a selected number of samples available phosphorus was determined by the Olsen sodium bicarbonate method (*7*), cation-exchange capacity by the ammonium acetate method, and exchangeable calcium by the versenate titration method (*10*).

RESULTS AND DISCUSSION

Table 1 presents data on the sugarcane yields obtained for each and for the total of three crops harvested. Table 2 summarizes the effect of lime on sugarcane yields.

[3] Hyperphosphate is obtained from the North African sedimentary deposits of phosphate of lime. It has an average content of 26 percent of total P_2O_5 while the commonly used superphosphate has only 19 percent. The available P_2O_5 however, was only 5.9 percent in the hyperphosphate, while almost all is available in the superphosphate.

There was a significant sugarcane yield response in the first crop and in the total of the three crops (table 1) when lime was added with 200 pounds

TABLE 1.—*Effect of superphosphate and hyperphosphate in the absence or presence of lime, upon yields of each of 3 crops, and the total yield of sugarcane variety PR-1000 grown in acid Lares clay*

Crop	Materials applied	Yield per acre of sugarcane at indicated P_2O_5 level				Mean-yields per acre for materials applied
		0	50 lb. per A.	125 lb. per A.	200 lb. per A.	
		Tons	*Tons*	*Tons*	*Tons*	*Tons*
First	Superphosphate	82.0	86.8	85.1	82.0	84.0
	Hyperphosphate	75.2	84.0	85.8	83.9	82.2
	Superphosphate plus lime	85.8	87.3	90.8	94.9	89.7
	Hyperphosphate plus lime	85.9	83.8	85.2	82.4	84.3
Second	Superphosphate	47.2	51.0	47.4	48.0	48.4
	Hyperphosphate	46.0	48.2	44.8	47.0	46.5
	Superphosphate plus lime	48.8	48.6	54.6	55.2	51.8
	Hyperphosphate plus lime	50.2	46.9	52.9	53.5	50.9
Third	Superphosphate	40.1	41.3	42.8	41.9	41.5
	Hyperphosphate	38.6	41.3	41.9	40.4	40.6
	Superphosphate plus lime	41.2	44.8	45.4	45.5	44.2
	Hyperphosphate plus lime	44.1	42.5	46.7	44.8	44.5
Total	Superphosphate	169.3	179.1	175.3	171.9	173.9
	Hyperphosphate	159.8	173.5	172.5	171.3	169.3
	Superphosphate plus lime	175.8	180.7	190.8	195.6	185.7
	Hyperphosphate plus lime	180.2	173.2	184.8	180.7	179.7

Item	L.S.D. for indicated means at the—							
	5-percent level for crops				1-percent level for crops			
	First	Second	Third	Total	First	Second	Third	Total
Materials applied	8.1	5.3	3.0	13.7	11.2	7.4	4.1	19.0
Different rates of P_2O_5 application for same material	8.5	6.5	4.6	16.0	11.4	8.6	6.2	21.3
Different materials for same rate of P_2O_5 application	10.9	7.7	5.0	19.5	14.9	10.5	6.7	26.4

of P_2O_5 as superphosphate to the soil. The significant yield response obtained in the third crop when lime and 200 pounds of hyperphosphate were added to the soil was not effective in causing a significant response in the total yield of the three crops.

There was a significant sugarcane yield response due to lime (table 2) in the second and third and in the total of three sugarcane crops.

Long-time field experiments under way at two other locations in Puerto Rico indicate that sugarcane yields can be maintained at practically maximum levels for a long period with an annual application of only 20 pounds of P_2O_5 per acre (*2*). One location was at the acid Vega Alta clay, a Red and Yellow Podzolic soil similar to Lares clay. Previous work (*3*) with tagged superphosphate added at the rate of 50 pounds of P_2O_5 per acre to acid Vega Alta clay, indicated that sugarcane absorbs most of the phosphorus from the soil. The mean amount derived from the soil was 99 percent 17 days after the application of the tagged superphosphate, and about 90 percent after 80 days. In limed plots the phosphorus absorbed from the soil was 99.5 percent 17 days after the application, and 87 percent 51 days afterwards (*3*). Liming the acid Vega Alta clay at the rate of 7 tons of limestone per acre was not effective in changing the amount of phosphorus absorption.

TABLE 2.—*Effect of lime on acid Lares clay upon yields of each, and of total yield, of 3 crops of sugarcane*

Crop	Mean yields		Least significant differences	
	Unlimed	Limed	5 percent	1 percent
	Tons/A.	*Tons/A.*		
First	83.1	87.0	5.7	7.9
Second	47.5	51.4	3.8	5.2
Third	41.0	44.5	2.1	2.9
Total	171.6	182.9	9.7	13.4

No sugarcane yield response was obtained in the experiment herein reported when different rates of P_2O_5 as superphosphate or hyperphosphate, up to 200 pounds P_2O_5 per acre, were added. Laboratory analyses indicate that the acid Lares clay supplies from 35 to 72 pounds of available P_2O_5 per acre. These results confirm those previously reported (*1*) from a number of field experiments in which possible needs of phosphorus fertilizers for sugarcane grown in coastal plain soils were provided though no responses were obtained. On the other hand, the use of lime in acid soils where sugarcane is grown has not yet been fully acknowledged. The beneficial effects of liming herein reported confirm those reported at earlier dates by several investigators (*4*, *6*), as well as those obtained at a more recent date by Pietri and Gómez-Montoya (*8*), after applying lime up to 80-percent base saturation to a soil where sugarcane was grown.

The data reported here (table 1) point to an interaction between lime and superphosphate. When a high level up to 200 pounds of P_2O_5 to the

acre was added to the soil, significant increases of sugarcane yields were obtained in the first crop and in the total of the three crops. The combined action of lime and P_2O_5 was not effective at the lower rates of 50 and 125 pounds of P_2O_5 to the acre.

The soil reaction of Lares clay 44 months after the 4 tons of limestone were applied, was still acid (pH 5.7–6.2), but the mean exchangeable calcium (table 3) increased to 8.2 m.e. per 100 g. of dry soil, 4.8 m.e. above the mean value for the unlimed soil, equivalent to 2.4 tons of residual limestone per acre. The exchangeable calcium of the unlimed soil was 25.0 percent of the total exchange capacity and that of the limed soil was 59.4 percent.

With the beginning of the fourth consecutive crop (third ratoon) on these plots, phosphorus applications were discontinued in an effort to measure any possible response that might become apparent with continuous phosphorus extraction from the soil.

TABLE 3.—*Range in pH, total exchange capacity, and exchangeable calcium of unlimed and limed plots in Lares clay*[1]

Treatment	Range in pH	Total exchange capacity per 100 g. of dry soil	Exchangeable calcium, Ca per 100 g. of dry soil	Percentage exchangeable Ca of total exchange
		M.e.	*M.e.*	
Unlimed	5.5–5.6	13.6	3.4	25.0
Limed	5.7–6.2	13.8	8.2	59.4

[1] Each value represents the mean of 12 samples taken at 0–8-inch depths 44 months after liming at the rate of 4 tons of $CaCO_3$ per acre.

SUMMARY

Data are reported here from a field experiment with sugarcane on acid Lares clay located in the humid area of Puerto Rico, at the Corozal Agricultural Experiment Substation. The effect of lime and of two sources of phosphorus fertilizers was tested. The experiment included superphosphate and hyperphosphate, each with or without lime, at four rates: 0, 50, 125, and 200 pounds P_2O_5 to the acre. Lime was used at the rate of 4 tons to the acre. Yield data are reported for a plant crop of sugarcane and for two succeeding ratoon crops. No significant differences were obtained attributable to either type or rate of phosphorus fertilizer when added to the acid soil. Liming caused significant increases in sugarcane yields in both ratoon crops and in the total of the three crops, amounting to 11.3 tons of sugarcane per acre. The highest significant increase of 24.3 tons of sugarcane per acre was obtained when lime was added with 200 pounds P_2O_5 per acre as superphosphate.

RESUMEN

Se presentan aquí los datos obtenidos de un experimento de campo con caña de azúcar en el suelo ácido Lares arcilloso, de la zona húmeda de Puerto Rico, en la Subestación de Corozal. Se estudió el efecto de la cal y de 2 abonos fosfáticos. Los tratamientos estudiados incluyeron superfosfato e hiperfosfato, con y sin cal, a razón de 0, 50, 125 y 200 libras P_2O_5 por acre. La cal se aplicó a razón de 4 toneladas por acre. Se informan los datos de rendimientos de una plantilla y 2 retoños de caña de azúcar. No se observaron diferencias significativas atribuíbles al tipo o a la cantidad de fósforo aplicada al suelo ácido. El uso de cal causó aumentos significativos en el tonelaje de ambos retoños y en las 3 cosechas aumentó el rendimiento total en 11.3 toneladas de caña por acre. El aumento significativo más alto, de 24.3 toneladas de caña por acre, se obtuvo cuando se aplicó cal y 200 libras de P_2O_5 por acre, como superfosfato.

LITERATURE CITED

1. Bonnet, J. A., Capó, B. G., and Riera, A., Lack of response of sugarcane to applications of phosphorus in Puerto Rico, *J. Agr. Univ. P. R.* **30** (3) 186–95, 1946.
2. Bonnet, J. A., and Lugo-López, M. A., Annual Report Commonwealth Project 7. Dept. of Soils, Univ. P. R., Agr. Exp. Sta. 1956, unpublished.
3. Bonnet, J. A., Riera, A. R., and Roldán, J., Radioactive studies with P^{32} in tropical soils and crops of Puerto Rico, *Soil Sci. Soc. Amer. Proc.* **19** (3) 283–4, 1955.
4. Gile, P. L., and Ageton, C. N., The red clay soil of Puerto Rico, P. R. (Federal) Agr. Exp. Sta. Bul. 14, 1914.
5. Jeffries, C. D., Bonnet, J. A., and Abruña, F., The constituent minerals of some soils of Puerto Rico, *J. Agr. Univ. P. R.* **37** (2) 114–39, 1953.
6. May, D. W., Sugarcane in Puerto Rico, P. R. (Federal) Agr. Exp. Sta. Bul. 9, 1910.
7. Olsen, S. R., Cole, C. V., Watanabe, F. S., and Dean, L. A., Estimation of available phosphorus in soils by extraction with sodium bicarbonate, USDA Cir. 939, 1954.
8. Pietri, R., and Gómez-Montoya, D., The response of sugarcane to liming of acid soils, Col. Agr. and Mech. Arts, Univ. P. R., personal communication.
9. Roberts, R. C., Soil survey of Puerto Rico, USDA in cooperation with Univ. P. R. Agr. Exp. Sta., Series 1936 (8) 1942.
10. U. S. Salinity Laboratory Staff, Diagnosis and improvement of saline and alkaline soils, p. 94, Agr. Handbook 60, USDA, 160 pp., 1954.

Influence of the Number of Fertilizer Applications on Pineapple Yields

George Samuels and Héctor Gandía Díaz[1]

INTRODUCTION

It has been the custom of pineapple growers in Puerto Rico to use large quantities of fertilizers in split applications. The fertilizer is supplied to pineapples in commercial production in from four to six applications per crop, using hand labor, with placement at the base of the plant to leave a good portion in the axils of the leaves. The average application per plant is about 1 ounce of mixed commercial fertilizer which, on a basis of 12,000 plants per acre, amounts to 750 pounds of fertilizer per acre per application. This amounts to 3,000 pounds of fertilizer for four applications and to 4,500 pounds for six.

Until work had been carried out on the control of biological parasitic factors it was the general opinion of many pineapple growers and research workers that, at least under Puerto Rican conditions, the pineapple plant had a poor root system, rooted very slowly, and was a poor feeder. Hence it must be fertilized heavily if good yields were to be obtained. However, this concept has since changed. We now realize that heavy nematode infestation and other insect and disease damage may weaken pineapple plants so that they no longer give a true picture of their own actual nutrient requirements.

It has been shown that pineapple yields can be doubled by treating soils against nematodes and soil-borne insects and by treating the plants against mealybugs (*1*).[2] Fertilizer experiments have revealed that optimum yields of pineapples can be obtained with much lower rates of fertilizer than were formerly used, if soils and plants are properly treated for control of insects (*4*).

After seeing that pineapple plants could grow vigorously and with less fertilizer, if properly treated, it was only natural for the grower to wonder how many fertilizer applications were necessary for good pineapple yields. The answer to this question is most important to the grower, as farm-labor wages are increasing rapidly. Therefore, any change which would decrease man-hours of labor by decreasing the number of fertilizer applications would be welcome. In order to determine whether fertilizer applications could be decreased for pineapples, if they were kept free from diseases and insects,

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[2] Italic numbers in parenthesis refer to Literature Cited p. 11.

experiments were initiated by the Agricultural Experiment Station of the University of Puerto Rico. This paper reports the results of such a pineapple-fertilizer experiment at Arecibo.

PROCEDURE

The experiment was planted on a Bayamón sandy clay at Bajadero, Arecibo. This soil is acid, browish-red, permeable, overlaying a deep-red slightly plastic but permeable clay subsoil. Limestone is present at a depth ranging from 6 to 10 feet. The pH of the topsoil and subsoil was 4.5. The field selected was treated with DD mixture (dichloropropane and dichloropropene) to control nematodes and with Aldrin to control white grubs and ants.

The plots consisted of three-row plantings of the Red Spanish variety, 20 plants to a row, or 60 per plot. The plants were 18 inches apart in the row and 1½ feet apart between rows, with a 4½ feet passageway between plots. This gave a plot size of 9 by 30 feet, or about $\frac{1}{161}$ acre. The slips were planted on July 16, 1954, and the fruit was harvested August 9–23, 1955. The fertilizer sources were as follows: Nitrogen from ammonium sulfate (20-percent N), phosphorus from superphosphate (20-percent P_2O_5), and potassium from potassium chloride (60-percent K_2O). The plants were sprayed with iron sulfate ($FeSO_4 \cdot 7H_2O$), on March 16, 1955 and May 15, 1955.

RESULTS

The yields obtained from the various fertilizer treatments are given in table 1. Application at time of planting was equal to or better than two or three applications of the same quantity of fertilizer. For example, 300 pounds of N, 60 pounds of P_2O_5, and 225 of K_2O per acre, when applied at time of planting (treatment 3, table 1), was equally as good if applied in two (treatment 7, table 1) or three applications (treatment 8, table 1).

Aside from this experiment, there has been evidence from other experiments in favor of a lower number of fertilizer applications for pineapples. This evidence is presented in table 2. For the experiment on Coto clay at Isabela (*5*), we see that in all cases yields were not significantly lowered when the lesser number of applications was used. This also held true for the pineapples grown on a Lares clay at Corozal (*4*).

DISCUSSION

The application of all of the fertilizer at time of planting was sufficient to supply the nutrient needs of the crop throughout its growing period without resort to split fertilizer applications. The use of one fertilizer application versus several has been shown to be a valid practice for sugarcane in Puerto Rico (*3*). This, of course, applies to those soils the texture of which

TABLE 1.—*Influence of time and number of fertilizer applications on the yields of a plant crop of Red Spanish pineapples at Arecibo, 1954–55*

Treatment No.	Treatment in pounds per acre			Time and number of fertilizer applications	Mean fruit weight	Yield of fruit per acre
	N	P_2O_5	K_2O			
					Pounds	*Tons*
1	100	20	75	All at time of planting	2.75	16.1
2	150	30	113	do.	2.94	17.2
3	200	40	150	do.	3.11	18.2
4	300	60	225	do.	3.19	18.6
5	150	30	113	½ at planting, ½ at 8 months	2.63	15.3
6	200	40	150	do.	2.86	16.7
7	300	60	225	do.	3.08	18.0
8	300	60	225	3 applications at 1, 4, and 8 months	3.06	17.9
Least significant difference needed between treatments at:						
5-percent level					0.19	1.11
1-percent level					.25	1.46

TABLE 2.—*The influence of the number of fertilizer applications on the yields of pineapples on various soils*

Amount of nitrogen applied per acre		Number of applications	Yields of fruit per acre
Soil and weight of each application	Weight of all applications		
Pounds	*Pounds*		*Tons*
Coto clay:			
80	160	2	12.7
40	160	4	13.3
120	240	2	13.0
80	240	3	13.9
Lares clay:			
84	84	1	12.0
28	84	3	13.0
56	112	2	13.7
28	112	4	13.6
84	168	2	15.8
56	168	3	15.0

Least significant differences needed between treatments at 5-percent level: 2.6.

is heavy enough, or their exchange capacity is high enough, that excessive leaching of plant nutrients does not occur.

The quantity of fertilizer applied rather than the number of applications made appears to be the more important factor for increasing pineapple

yields. For one application at time of planting, doubling the rate of fertilizer application increased yields from 16.1 to 18.2 tons per acre (treatments 1 and 3, table 1). Raising application rates one-half again (treatment 4) did not give significantly higher yields than those for doubling the rate (treatment 3). Where two fertilizer applications were made, increasing the rate applied per application also increased yields. In this instance significant yield increases were obtained when rates were doubled and tripled (table 1, treatments 5, 6, and 7).

The entire matter of split applications of fertilizer for pineapples must be re-examined in light of our present-day knowledge of pineapple nutrition and culture. The practice of using numerous applications of fertilizer for pineapples was based on the knowledge that very poor yields were obtained in the past unless many applications were made. This, of course, was necessary, as the pineapple plant was sick, weak, and starved by the ravages of the biological parasitic factors which attacked it. Before proper attention was given to these factors the pineapple plant's root system was attacked and almost entirely destroyed by nematodes, white grubs, and root rots, and the leaves and stem were invaded by mealybugs. Such a plant could not function normally. The intake of nutrients through the root system was limited. Fertilizer was applied at the base and in the axils of the lower leaves to feed such plants. It was by such spoon-feeding in numerous applications that they were kept in production.

With the proper control of nematode infestation and other insect and disease damage, the pineapple has become almost a different plant in its growth habits. Now it produces a large vigorous root system quite soon after planting. No longer can the plant be uprooted easily at 4 to 5 months of age with a light pull. In this particular experiment at Palo Blanco, Arecibo, the use of two hands and much effort was needed to uproot plants just 1 month after planting. The pineapple plant with a large vigorous root system at its disposal has a large volume of soil from which to extract its nutrients. It is no longer limited to feeding from the axils of its leaves and a few cubic inches of soil surrounding the base of the plant. Therefore, with increases in root volume there is a decrease in number of applications and quantity of fertilizer needed.

Of vital interest to the farmer is the fact that fewer fertilizer applications are needed for growing pineapples. Farm-labor costs are increasing rapidly in Puerto Rico; thus a practice which can save labor means more return to the farmer.

Economic surveys have shown that in 1954–55 labor costs comprised 44 percent of farm costs, and fertilizers 19 percent (*2*). Therefore, if the number of fertilizer applications can be reduced from six to about two or three, and fertilizer rates decreased to about half in many cases, the saving in money to the farmer would be great. It would not be fair to say that

fertilizer applications should be cut to one at time of planting in all cases. However, the evidence presented clearly indicates that fertilizer applications can be reduced without any decrease in yields of pineapples. This, of course, is based on the fact that the pineapple plant is free from any limiting biological parasitic factors and is free to develop a large ample root system, which it is capable of doing.

SUMMARY

Investigation of the number of fertilizer applications needed for optimum yields of Red Spanish pineapple on a Bayamón silty clay at Bajadero, Arecibo showed that:

1. One application at time of planting was equal to, or better than, splitting the same quantities of fertilizer into two or three applications.

2. The total fertilizer applied was more important than number of applications made.

A discussion is presented in which the credit for the lesser number of fertilizer applications is given to the increased vigor of the pineapple plant when kept free from disease and insect attack.

RESUMEN

La investigación llevada a cabo con el objeto de determinar el número de aplicaciones de abono que son necesarias para obtener los rendimientos óptimos de la piña Española Roja, en un suelo Bayamón limo arcilloso ubicado en el barrio Bajadero de Arecibo, reveló lo siguiente:

1. Una sola aplicación de abono al tiempo de la siembra fué igual o mejor que el dividir la misma cantidad de abono y aplicarla en dos o tres ocasiones.

2. La cantidad de abono aplicado en total fué más importante que el número de sus aplicaciones.

En el texto de este trabajo se discute el hecho de que el mayor vigor de la planta de piña, cuando está libre de insectos y enfermedades contribuye al que no haya que hacerle más de una aplicación de abono.

LITERATURE CITED

1. Alvarez García, L. A., and López Matos, L., Influence of root knot nematodes on the decline in vigor of the Red Spanish variety of pineapple in Puerto Rico, *J. Agr. Univ. P. R.* **38** (1) 61–72, 1954.
2. Vázquez Calcerrada, Pablo, Costos e ingresos comparativos entre la empresa de piña y de la caña, Agricultural Economics and Rural Sociology Publication 14, Agr. Exp. Sta. Univ. P. R., Río Piedras, Dec. 1951.
3. Samuels, George, and Capó, B. G., Research with sugarcane fertilizers in Puerto Rico, 1910–54, Tech. Paper 16, Agr. Exp. Sta., Univ. P. R. March 1956.
4. Samuels, George, Landrau, P. Jr., and Olivencia, R., Response of pineapples to the application of fertilizers, *J. Agr. Univ. P. R.* **39** (1) 1–11, 1955.
5. Samuels, George, Alers-Alers, S., and Jackson, G. C., The influence of fertilizers on pineapple yields on a Coto clay, *J. Agr. Univ. P. R.* **42** (1) pp. 12–26, 1958.

Influence of Fertilizers on Yields of Pineapples on a Coto Clay

G. Samuels, S. Alers-Alers, and G. C. Jackson[1]

INTRODUCTION

Pineapple ranks as the most important cash crop among the fruits of Puerto Rico. In 1954–55, its farm value was $2,422,000. It ranks third in cash value as an export crop, the greater part of which is shipped to the United States for consumption as fresh or canned pineapple.

Most of the pineapples are grown in an area along the north-central coast of Puerto Rico extending westward from Vega Alta to Arecibo—a distance of about 42 miles from east to west and 16 miles from north to south (fig. 1). Almost nine-tenths of all commercial pineapples grown in Puerto Rico are produced in this area.

In 1955, the Land Authority of Puerto Rico began a program to expand the cultivation of pineapples in Puerto Rico. To stimulate this program, new growers were offered credit, technical aid, minimum price guarantees, and other facilities if they would contract to grow and deliver pineapples to the Land Authority canning factory at Manatí. This new factory has a larger capacity for canning pineapples than present acreages can provide. Thus, an expanded program of planting is needed to produce the required volume of fruit for efficient operation of this factory.

One of the principal areas now opened to new pineapple production is the zone of Camuy, Quebradillas, and Isabela. The acreage devoted to pineapples in this area was very small before 1955. Fortunately, some of the soils encountered there belong to the Espinosa, Almirante, Vega Alta, and Bayamón series, which predominate in the regular pineapple areas. However, the Coto soil series and its related Matanzas soil series, offer a large acreage of soils heretofore not normally planted to pineapples. Coto clay and sandy clay comprise an area of about 6,000 acres and the Matanzas clay an additional 1,500 acres of land suitable for growing pineapples.

OBJECTIVES

It was deemed important to obtain information on the fertilizer needs of Coto soils when growing pineapples. The Station, therefore, established a series of fertilizer experiments on Coto clay, the main soil type of the Coto series, in order to obtain such information for growers who wish to plant pineapple on these soils.

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PROCEDURES

Two experiments were performed: One was concerned with the quantities and number of applications needed per acre of the major fertilizer elements (nitrogen, phosphorus, and potassium); the other concerned the minor-element fertilizers, iron especially. These pineapple experiments were planted at the Isabela Substation.

Coto clay is a friable soil with excellent internal drainage, which occurs in the nearly level areas in the townships of Isabela, Quebradillas, and Camuy. The soil pH was 6.3. The field selected had never been planted to pineapples and was in sugarcane prior to being used for this experiment.

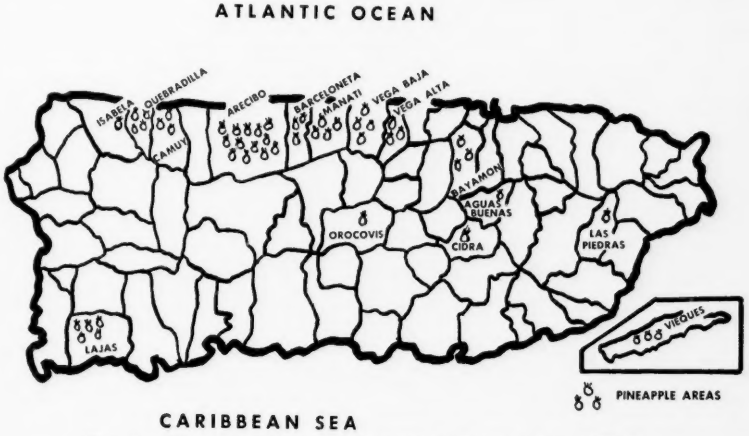

FIG. 1.—The pineapple-growing areas of Puerto Rico, 1955–56.

To control nematodes the field was injected on September 28, 1954, with DD mixture (dichloropropane and dichloropropene) at a rate of 115 pounds per acre. For the control of white grubs (*Phyllophaga portoricensis*), the soil was treated with Aldrin on September 14, 1954, at a rate of 4 pounds of technical Aldrin per acre.

The treatments for the major-element experiment (table 1) included seven fertilizer levels and four fertilizer applications. The experimental design was a randomized split-plot one, with the number of fertilizer applications compared in the main plots and the various fertilizer levels in the split-plots. There were six replications of each split-plot treatment. The treatments were so arranged that all plots received fertilizer at time of planting; all plots, except those labeled "one application," received another fertilizer application 4 months after planting; all plots, except those marked "one and two applications," received a third application 8

months after planting; and only the plots marked "four fertilizer applications" received fertilizer again 12 months after planting.

The source of nitrogen used was ammonium sulfate (20-percent N), the phosphorus source was superphosphate (20-percent P_2O_5), and the potassium source was potassium chloride (60-percent K_2O). The various components were weighed and mixed before applying in the field. For the first application the fertilizer was applied to the soil in the row below the plant. For all other applications the fertilizer was broadcast by hand near the base of the plant and the axils of the lower leaves.

TABLE 1.—*Fertilizer treatments used in the pineapple experiment, Isabela Substation, 1954–56*

Fertilizer applied in pounds per acre per application of—			Total fertilizer applied in pounds per acre for the number of fertilizer applications indicated—[1]											
			First			Second			Third			Fourth		
N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
0	40	40	0	40	40	0	80	80	0	120	120	0	160	160
40	40	40	40	40	40	80	80	80	120	120	120	160	160	160
80	0	40	80	0	40	160	0	80	240	0	120	320	0	160
80	20	40	80	20	40	160	40	80	240	60	120	320	80	160
80	40	0	80	40	0	160	80	0	240	120	0	320	160	0
80	40	40	80	40	40	160	80	80	240	120	120	320	160	160
120	40	40	120	40	40	240	80	80	360	120	120	480	160	160

[1] 1st fertilizer application at time of planting, 2nd fertilizer application 4 months after planting, 3d fertilizer application 8 months after planting, and 4th fertilizer application 12 months after planting.

The sub- or split-plots consisted of three rows, 26 feet long. The pineapple plants were planted 18 inches apart in the rows with 1½ feet between rows and 4½ feet between plots, making a plot size of about $\frac{1}{210}$ acre in area. There were 16 plants per row, or 48 plants per plot, which corresponds to about 11,675 plants per acre. Slips of the Red Spanish variety, the main commercial pineapple variety of the Island, were planted October 28–30, 1954. The first fertilizer application was on October 24, 1954, the second on February 25, 1955, the third on June 25, 1955, and the fourth on October 25, 1955. The plants were treated with acetylene on November 14, 1955, to induce flowering. This consisted of spraying the crown of the plant with 25 to 30 ml. of a solution made by dispersing 2 ounces of calcium carbide in 5 gallons of water in a closed container.

The minor-element experiment consisted of a randomized incomplete-

block design with 13 treatments and 4 replications. The size of plot and planting distances were the same as that for the major-fertilizer-element experiment. All treatments received a 16–8–8 fertilizer at rates equivalent to 2,000 pounds per acre, divided into four applications. Time of planting and dates of application of the fertilizer were the same as those for the other experiment. The treatments and the rates and methods of application are given in table 3 under Results.

RESULTS

MAJOR ELEMENTS

Nitrogen

Nitrogen fertilizer was of prime importance in securing high yields of pineapples in this experiment. Yields increased with increased application of nitrogen. The highest yields of 18.6 tons of pineapples per acre were obtained with 480 pounds of nitrogen per acre (table 2). The need of nitrogen was visible from the very start of the experiment. Those plots receiving no nitrogen showed a chlorosis even 1 month after planting. During the progress of the experiment all no- or low-nitrogen plots were light yellow-green in color and showed poor growth. The higher nitrogen-treatment plants all had a dark-green color, large well-formed leaves, and showed good growth.

It appears that the total nitrogen applied per acre, rather than the number of applications made, was of more importance insofar as influence of nitrogen on yields was concerned. In figure 2 the quantity of nitrogen applied per acre is plotted against the yield of fruit per acre. The number of applications used to apply the nitrogen are indicated at each point. We can see many instances where the same quantity of nitrogen gave no significant difference in yield, no matter how many applications were used. For example, 240 pounds of nitrogen, when divided into two fertilizer applications, no more gave a significant difference in yield than when divided into three. Also 320 pounds of nitrogen per acre, split into four applications, produced no significantly different yield than 360 pounds in three applications. The highest yield of 18.6 tons per acre was obtained by the use of 480 pounds of nitrogen per acre split into four applications. However, the design of the experiment was such that this rate of 480 pounds of nitrogen was not applied in two or three applications. It appears that, in all probability, the use of 480 pounds per acre of nitrogen would have given as high a yield, even if fewer than the four applications had been used. As stressed before, the quantity of nitrogen applied per acre and not the number of applications appears to be a main limiting factor for high pineapple yields.

Phosphorus

There was no significant response to phosphate fertilizers, regardless, of rate or number of applications made. The use of rates up to 160 pounds of

TABLE 2.—*The yields of pineapple as influenced by various fertilizer levels and number of applications at Isabela Substation, 1954–56*

Treatment in pounds per acre per application of—			Mean yield of pineapple per acre for the number of fertilizer applications indicated				Means
N	P_2O_5	K_2O	1	2	3	4	
			Nitrogen (N)				
			Tons	*Tons*	*Tons*	*Tons*	*Tons*
0	40	40	8.6	10.6	10.5	11.3	10.2
40	40	40	9.1	10.8	13.2	13.3	11.4
80	40	40	9.9	12.7	13.9	16.5	13.2
120	40	40	10.9	13.0	15.8	18.6	14.6
			Phosphorus (P_2O_5)				
80	0	40	10.1	11.4	13.0	16.2	12.7
80	20	40	8.7	12.2	14.4	16.3	12.9
80	40	40	9.9	12.7	13.9	16.5	13.2
			Potassium (K_2O)				
80	40	0	9.9	10.5	12.9	15.2	12.1
80	40	40	9.9	12.7	13.9	16.5	13.2
Mean of all treatments per application			9.6	11.5	13.4	15.3	12.4
Least significant difference needed for comparisons between fertilizer treatments of same application at:							
5-percent level			1.85	1.85	1.85	1.85	0.92
1-percent level			2.50	2.50	2.50	2.50	1.25
Least significant difference needed for comparisons between mean of all treatments per application at: 5-percent level 1.85; 1-percent level 2.50.							
Least significant difference needed for comparisons between any fertilizer treatment at any number of applications at: 5-percent level 2.61; 1-percent level 3.42.							

P_2O_5 per acre did not materially increase nor decrease yields. Previous work in Puerto Rico had shown that, for other pineapple soils, phosphate ferti-

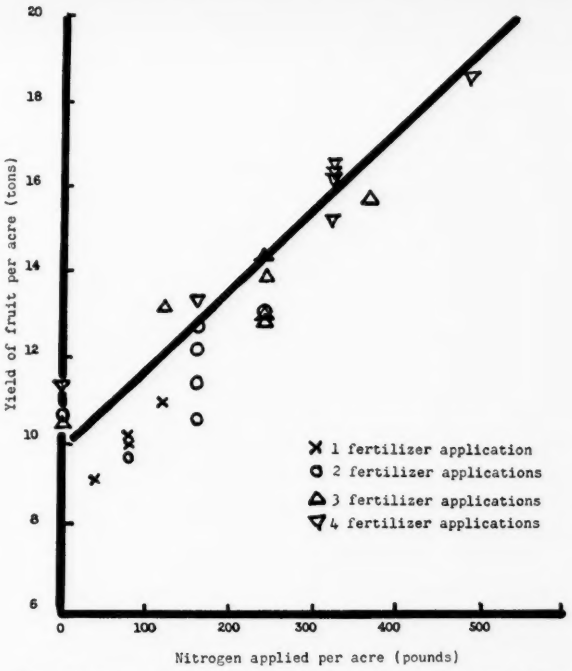

FIG. 2.—The influence of the rate at which nitrogen was applied per acre on yields of pineapples.

lizers were needed in only small quantities. Rates higher than 56 pounds P_2O_5 per acre caused a significant decrease in yields (*4*).[2]

Before undertaking these experiments with pineapples on a Coto clay, it was thought that a good response should be obtained from the use of phosphate fertilizers. This premise was based on the known fact that for sugarcane, a crop with a low phosphate requirement, significant responses have been obtained with phosphate fertilizers on Coto clay (*1*). The lack of response of pineapples to phosphate applications on a Coto clay appears once again to indicate that pineapples have very low phosphate needs, and to stress the undesirability of high phosphate applications for pineapples in the Coto soil series.

Potassium

A yield response was obtained from the use of potash fertilizers. Except for the second application, no significant increase was obtained, however

[2] Italic numbers in parentheses refer to Literature Cited, p. 26.

(table 2). But the mean data on the applications indicate that potash fertilizers had a significant influence in increasing yields.

It is of interest to note that responses to potash applications are not obtained for sugarcane on a Coto clay (*1*), whereas they are obtained with pineapples. Other pineapple soils have shown responses to potash fertilizers, and it appears that the Coto clay also requires potash applications for optimum pineapple yields.

Number of Fertilizer Applications

The number of fertilizer applications significantly influenced the yields of fruit (table 2). Yield increases were obtained with each additional fertilizer application. However, as mentioned previously, credit is due primarily to the total quantity of fertilizer applied—especially nitrogen. Thus we cannot definitely state the exact number of applications needed. Recent experiments have shown that, in soils such as the Bayamón sandy clay, the fertilizer applied in one application at time of planting is as good as several applications totaling the same amount of fertilizer. For Lares clay two to three fertilizer applications were sufficient for optimum yields.

Leaf Analysis

Leaf samples were taken to determine whether foliar diagnosis of the pineapple plant was useful as a means of determining the crop's fertilizer needs. Previous work in Puerto Rico (*5*), although limited to one crop, had indicated that foliar diagnosis might be practicable for pineapple.

The leaf values obtained are given in table 3. They are lower in leaf nitrogen, phosphorus, or potassium than were obtained in previous experiments in other areas.

NITROGEN. The leaf-nitrogen values for the various applications showed a significant linear correlation with the relative yields of pineapples per acre. Although leaf-nitrogen values were somewhat lower as compared with previous leaf samples from other pineapple areas, there was a definite increase in leaf nitrogen with increasing nitrogen applications and increasing yields (table 3). The equations obtained relating leaf-nitrogen values (X) with relative yields of fruits per acre (Y) for the three fertilizer applications were:

$$Y = 265.7\ X - 38.5 \text{ (1 application, leaf sample at 4 months)}$$
$$Y = 66.9\ X + 53.4 \text{ (2 applications, leaf sample at 8 months)}$$
$$Y = 118.7\ X - 37.2 \text{ (3 applications, leaf sample at 12 months)}$$

The resultant equations were all highly significant. The coefficient of determination, or prediction value ($r^2 \times 100$), for these equations averaged

98.6 percent. That is to say, 98.6 percent of the variation of leaf nitrogen related to relative yields of fruit was explainable by these equations.

Although there were significant correlations between leaf nitrogen and yields for each individual fertilizer application, the leaf-nitrogen values increased with each sampling after each application. Thus we find that leaf-nitrogen values of 0.52, 0.80, and 1.16 percent were all associated with

TABLE 3.—*Nutrient content of pineapple leaves from plant crop at Isabela Substation, 1954–56*

Treatment in pounds per acre per application of—			Nutrient content of pineapple leaves, dry-weight basis, for number of fertilizer applications indicated			Relative yields of pineapples per acre for number of fertilizer applications indicated		
N	P_2O_5	K_2O	1[1]	2[2]	3[3]	1	2	3
			Nitrogen					
			Percent	*Percent*	*Percent*			
0	40	40	0.44	0.51	0.91	79	82	67
40	40	40	.46	.57	.98	84	83	84
80	40	40	.48	.76	1.08	91	98	88
120	40	40	.52	.80	1.16	100	100	100
			Phosphorus					
80	0	40	0.07	0.09	0.12	101	90	94
80	20	40	.03	.09	.13	88	96	104
80	40	40	.05	.09	.15	100	100	100
			Potassium					
80	40	0	2.93	2.18	2.40	100	91	94
80	40	40	3.13	3.06	2.70	100	100	100

[1] Leaf sample taken 4 months after planting.
[2] Leaf sample taken 8 months after planting.
[3] Leaf sample taken 12 months after planting.

a relative yield of 100 for each particular fertilizer application (table 3). Since each successive fertilizer application meant that more nitrogen was being applied, we should expect increased leaf-nitrogen values and increased yields of fruit. It was felt that a more comprehensive picture could be obtained if the relative yield calculations for nitrogen were utilized as a basis of 100, the highest yield obtained with the largest nitrogen application. Therefore, 18.6 tons of pineapples obtained with 480 pounds of nitrogen was assigned a relative yield of 100, and the relative yields for the other nitrogen treatments were then calculated and associated with their leaf-nitrogen

values. The resultant equation obtained was $Y = 42.9\ X + 32.8$, and it was highly significant, having a prediction value of 92 percent. This equation covers the entire range of yields obtained from the various rates and number of applications of nitrogen (fig. 3).

It is interesting to note that leaf-nitrogen and relative yield values from a previous pineapple fertilizer experiment at Corozal on a Lares clay (*5*), when plotted, came close to the equation found for this experiment on Coto

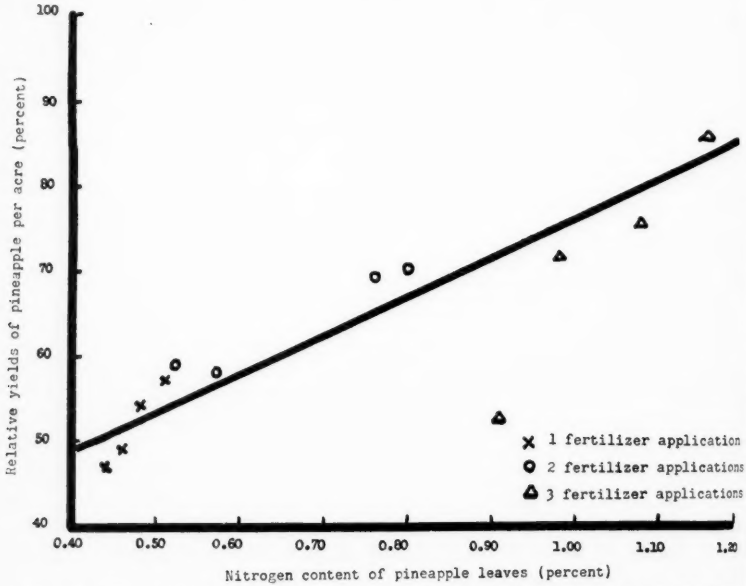

FIG. 3.—The relationship between the leaf-nitrogen content of Red Spanish pineapples and relative yields of fruit per acre for various numbers of fertilizer applications.

clay. For the Corozal experiment a relative yield of 100 was associated with a leaf-nitrogen value of 1.66 percent; for the Coto clay, using the equation $Y = 42.9\ X + 32.8$, a relative yield of 100 was linked to a leaf-nitrogen value of 1.57 percent.

Aside from the question of the most suitable tissue for leaf analysis in pineapple, we should ascertain the best time to take leaf samples. Previous work on sugarcane (*3*) has indicated that leaf samples taken at a cane age of 3 months best indicated differences in the nitrogen status of the plant and gave the highest correlations with yields. As shown in figure 4, the differences in leaf nitrogen attributable to the fertilizer applied were best

displayed 4 months after fertilizing. At 2 months after an application, the fertilizer had not been adequately absorbed by the plant for all treatments; and at 8 and 12 months, differences caused by treatments had diminished greatly or disappeared.

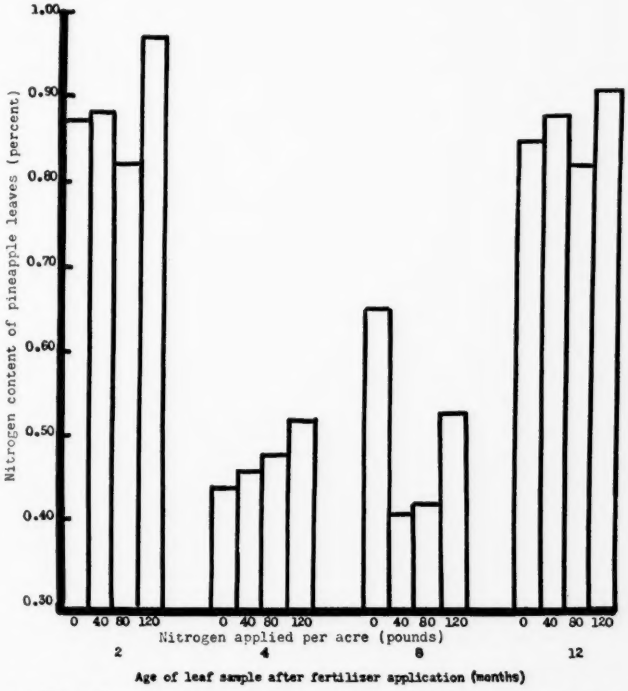

FIG. 4.—The influence of the age of the leaf sample after fertilizer application on the nitrogen content of the pineapple leaf.

PHOSPHORUS. Leaf-phosphorus values showed no significant relationship with pineapple yields. Inasmuch as phosphate fertilizers did not influence yields, we can suppose that the leaf values obtained were for optimum levels. For a Lares clay, a leaf-phosphorus level of 0.17 percent (*5*) was found to be a safe minimum for good pineapple yields. The values obtained for this experiment indicate that leaf-phosphorus levels as low as 0.09 percent were adequate on a Coto clay.

POTASSIUM. There was a significant linear relationship between leaf potassium and relative yields of pineapples per acre. The leaf values for potassium were all lower than those obtained at Corozal (*5*) which ranged

above 4 percent. For the Coto clay, leaf-potassium values near 3 percent were associated with the optimum yields of fruit.

MINOR ELEMENTS

Iron

The yields of pineapple were increased significantly by the use of ferrous sulfate sprays. The yield increase obtained was 1.4 tons of pineapples per

TABLE 4.—*Yields of pineapples from minor-element fertilizer experiment at Isabela Substation, 1956*

Treatment No.	Treatment[1]	Rate of application per acre	Number of applications	Method of Application	Yield of pineapples per acre
		Pounds			*Tons*
1	Control	0	0	None	16.0
2	$FeSO_4$	12[7]	4	Spray	17.4
3	Fe-EDTA[2]	2[7]	4	do.	17.2
4	Fe-EDTA on vermiculite[3]	40	1	Soil	16.4
5	FTE[4]	100	1	do.	17.1
6	NU-IRON[5]	3[7]	4	Spray	17.0
7	MgO[6]	300	1	Soil	17.4
8	$ZnSO_4$[6]	50	1	do.	16.9
9					

Least significant difference needed between treatments at: 5-percent level 1.40.

[1] All treatments received 2,000 lb. of a 16–8–8 fertilizer per acre in 4 applications.
[2] A sodium ferric ethylenediamine tetra-acetate (12-percent Fe); Sequestrene NaFe.
[3] Fe-EDTA absorbed on vermiculite (6-percent Fe).
[4] A relatively insoluble powdered glass containing Mn, Fe, Zn, Cu, B, and Mo.
[5] A commercial preparation of iron malonate (30-percent Fe).
[6] Also received treatment No. 2.
[7] Dissolved in 100 gal. water.

acre, or 9 percent more than when no iron was applied (table 4). A total of four spray applications as applied at 2-month intervals beginning when the plants were 2 months old. The rate used was 12 pounds of ferrous sulfate ($FeSO_4 \cdot 7H_2O$) in 100 gallons of water per acre.

It is a common practice for growers to use ferrous sulfate as the source of iron to control iron chlorosis in pineapple. The results obtained here indicate that the Coto clay needs iron sprays for best growth of pineapples, as do the other pineapple soils of Puerto Rico.

A new source of iron, chelated iron, has been used successfully in treating iron deficiencies in citrus and ornamental plants (*6*). Chelated iron is

composed of a complex organic salt usually combined with the metallic iron. The extremely stable compound fixes the metallic iron added and keeps it soluble so that it can be absorbed readily by the root system or leaves of the growing plant or tree. The chelates were tried in both soil and spray applications, and they did not give responses better than or equal to those produced by the regularly used ferrous sulfate (see table 4).

The use of the chelated iron as a spray at the rate recommended by the manufacturer—2 pounds per acre—was slightly inferior to ferrous sulfate in increasing yields. Inasmuch as chelated iron costs about 8 to 10 times as much as ferrous sulfate, there appears to be no advantage at present for its use by the farmer as an iron source for pineapples during the first year of the crop. Chelated iron does have one special advantage in that it can be used in spray form without harm when the plants are fruiting, whereas ferrous sulfate will burn the fruit.

Iron malonate (commercially known as NU-IRON) containing 30-percent iron when applied as a spray was also unsuccessful in increasing yields of pineapples significantly (table 4).

Spraying with iron salts involves an expense that could be reduced if the iron could be applied as a soil application. Inorganic iron salts much as ferrous sulfate become readily fixed in the soil and do not provide sufficient iron to the plant. The use of chelated iron in a soil application was believed to be a possible means of providing the needed iron to the plant. However, the data show that chelated iron, when added to the soil at the rate of 40 pounds per acre, did not give as good a control of iron chlorosis as ferrous sulfate sprays.

Another source used for adding iron as well as other mineral elements to the soil was fritted trace elements (FTE). This agricultural "frit" is basically a glass which is relatively insoluble, but which supplies traces of minor elements to growing plants. It is made by heating the various minor elements with a ceramic-making material at a very high temperature, and the resultant molten mass is allowed to flow into cold running water where it is fragmented into many small pieces. The process is known as "fritting", and the resultant product is "frit". This agricultured frit has proved to be an economical means of supplying minor elements slowly over a period of a few years (*7*).

The results obtained indicate that FTE does not increase yields as much as the ferrous sulfate sprays. However, the difference obtained between the two treatments was very small (table 4). The present price of the frit is about the same as that of ferrous sulfate per pound, but when used at recommended rates, about twice as much FTE as ferrous sulfate was required per acre. However, from the standpoint of economy of application, the frit, which need be applied only once, is more economical to use than

the ferrous sulfate sprays. Another economical advantage yet to be determined is whether the frit produces sufficient iron for the ratoon crops. If so, then FTE offers a definite economical advantage as a source of iron for pineapples as compared to chelates and ferrous sulfate sprays.

Magnesium

The pineapples showed no significant response to magnesium applications. The use of 300 pounds per acre of magnesium oxide did not increase yields over those receiving none (treatment 7 minus treatment 2, table 4). The plants not treated with magnesium oxide did not display any visual deficiency symptoms. Visual symptoms of magnesium deficiency on pineapples has been detected recently on pineapples growing on the Bayamón sandy clay in areas near Manatí.

Zinc

The addition of zinc sulfate to the soil at a rate of 50 pounds per acre failed to increase pineapple yields (treatment 8 minus treatment 2, table 4). Landrau and Samuels reported no responses were obtained with zinc sulfate on a Bayamón sandy clay (*2*).

SUMMARY

This paper reports the results obtained in studies carried out on Red Spanish pineapples to determine their major- and minor-element fertilizer requirements for Coto clay soils. The experimental results may be summarized as follows:

1. Nitrogen was of prime importance in securing maximum yields of pineapples. The use of 480 pounds of nitrogen per acre gave the highest yields.
2. There was no significant response to phosphate fertilizers.
3. Yield responses were obtained from the use of potash fertilizers.
4. The number of fertilizer applications significantly influenced the yield of fruit; however, credit was due mainly to the total fertilizer applied—especially nitrogen.
5. The leaf analyses obtained were lower in nitrogen, phosphorus, and potassium than for other experiments.
6. Leaf-nitrogen values showed a significant correlation with relative yield of pineapples.
7. For Coto clay, leaf-phosphorus values of 0.09 percent and leaf-potassium values of 3 percent were associated with optimum yields of fruit.
8. The yields of pineapples were increased by the use of ferrous sulfate sprays.
9. Chelated iron as a spray or in soil applications gave no better results in increasing yields than ferrous sulfate sprays.

10. Iron malonate applied as a spray was unsuccessful in increasing pineapple yields.

11. The use of a glass frit containing iron and other minor elements held in a relatively slowly soluble form gave yields similar to the use of the ferrous sulfate sprays, but at a lower cost per acre.

12. Magnesium oxide and zinc sulfate did not increase yields on a Coto clay.

RESUMEN

Este trabajo informa los resultados obtenidos en estudios llevados a cabo en siembras de piña de la variedad Española Roja en suelos Coto arcillosos para determinar sus requisitos de abonamiento en cuanto a los elementos mayores y menores.

Los resultados experimentales pueden resumirse como sigue:

1. El nitrógeno tuvo primordial importancia en la producción de los más altos rendimientos de frutas. La aplicación de 480 libras de nitrógeno por cuerda produjo los rendimientos mayores.

2. No hubo una respuesta significativa a las aplicaciones de abono con fósforo.

3. Se obtuvo rendimientos satisfactorios con el uso de abonos potásicos.

4. El número de aplicaciones de abono influyó significativamente en los rendimientos. Sin embargo, por ésto se le da crédito mayormente a la cantidad total de abono aplicado, especialmente al nitrógeno.

5. Los análisis foliares efectuados demostraron valores más bajos de nitrógeno, fósforo y potasio, al compararse con otros experimentos.

6. Los valores de nitrógeno en la hoja demostraron una correlación significativa con los rendimientos relativos.

7. En los terrenos Coto arcillosos, los valores de 0.09 por ciento de fósforo en la hoja y de 3 por ciento de potasio en la hoja se asociaron con los mejores rendimientos.

8. Los rendimientos aumentaron cuando se hicieron aspersiones de sulfato de hierro.

9. Ni las aspersiones a las hojas ni las aplicaciones al terreno, de hierro chelado, produjeron un mayor aumento de los rendimientos que el producido por las aspersiones de sulfato de hierro.

10. Las aspersiones de malonato de hierro no lograron aumentar los rendimientos.

11. El uso de un compuesto especial conteniendo hierro y otros elementos menores, integrado en forma que eventualmente pudiera disolverse muy gradualmente, dió resultados similares a las aspersiones con el sulfato ferroso, pero a un costo menor por cuerda.

12. El óxido de magnesio y el sulfato de zinc resultaron inefectivos para aumentar los rendimientos en los terrenos Coto arcillosos.

LITERATURE CITED

1. Landrau, P., Jr., and Samuels, G., Response of four sugarcane varieties to fertilizers during the first Isabela cycle, 1946–51, *J. Agr. Univ. P.R.* **38** (2) 73–95, 1954.
2. Landrau, P., Jr., and Samuels, G., Results of lime and minor-element fertilizer research in Puerto Rico, 1945–50, *J. Agr. Univ. P.R.* **40** (4) 224–34, 1956.
3. Samuels, G., and Capó, B. G., Effects of level of a fertilizer element on the uptake and concentration of that element and other elements in a plant, *Agron. J.* **44** (7) 352–7, 1952.
4. Samuels, G., Landrau, P., Jr., and Alers Alers, S., Influence of phosphate fertilizers on pineapple yields, *J. Agr. Univ. P.R.*, **40** (4) 218–23, 1956.
5. Samuels, G., Landrau, P., Jr., and Olivencia, R., Response of pineapples to the application of fertilizers, *J. Agr. Univ. P.R.* **39** (1) 1–11, 1955.
6. Wallace, A., North, C. P., Kofranek, A. M., and Lunt, O. R., Chlorosis in ornamentals, *Calif. Agr.* **7** (10) 13–4, 1953.
7. Walters, E. I., Agricultural fruit, *Farm Chemicals* **115** (8) 30–4, 1952.

Observations on the Boron-Manganese Relationships in Soybean and Corn Plants

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INTRODUCTION

Manganese-toxicity chlorosis of pineapple has been reported in Puerto Rico. Such toxicity may result from the high-soluble manganese and low-soluble iron contents of substrates (*3*).[2] Schapelle (*5*) studied the effect of trace elements on the growth and development of pineapples, emphasizing the cause and prevention of chlorosis. His studies indicated that aluminum and boron seemed to prevent the manganese-induced chlorosis, probably by rendering the iron more available for normal chlorophyl synthesis.

In an attempt to obtain more information on the possible corrective effect of boron on manganese-induced chlorosis, experiments were conducted at Río Piedras under greenhouse conditions, using soybeans and corn as indicator plants.

EXPERIMENTAL PROCEDURE

SOYBEAN EXPERIMENT

Seed of the Otootan variety of soybeans, selected for uniformity of size and shape, were sterilized in a 1–1,000 mercuric bichloride solution for 15 minutes, then completely washed in distilled water and finally sown in purified quartz sand in wooden boxes. The sand was previously flooded with distilled water and then flushed with the basic nutrient solution to be used in the experiment, but diluted to one-third concentration. Traces of minor elements were added, except boron and manganese. Seed germination was good enough and by the fifth day after sowing relatively uniform seedlings were produced. The best were selected and transferred to purified quartz sand in pots heavily coated with paraffin. Before the seedlings were transplanted, the sand was flushed with distilled water and then supplied with the same dilute basic nutrient solution as was supplied to the seedlings in the sand germinators.

The seedlings were maintained on the dilute nutrient solution, which in addition to the usual minor elements, contained 0.25 p.p.m. of boron and manganese for a period of 1 week. At the end of this period all plants appeared healthy and vigorous and the boron-manganese nutrient treatments

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[2] Italic numbers in parentheses refer to Literature Cited, p. 34.

were started. A slightly modified four-salt solution used by Shive in boron studies was used in this study. The composition of the nutrient solution was as follows, in mols: KH_2PO_4, 0.0020; $NaNO_3$, 0.0038; $MgSO_4$, 0.0028; $CaCl_2$, 0.0020; with iron and zinc added in quantities equivalent to 1.0 and 0.25 p.p.m., respectively. Five boron levels were used: 0, 0.005, 0.5, 3, and 5 p.p.m. Six manganese concentrations were employed at each boron

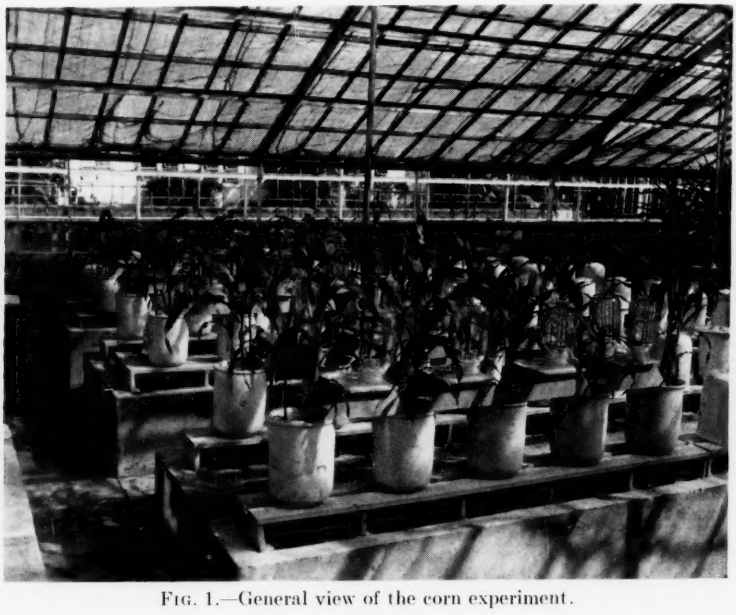

FIG. 1.—General view of the corn experiment.

level: 0, 0.001, 0.01, 0.25, 2, and 5 p.p.m., making a total of 30 treatments. Three plants were used in each culture.

CORN EXPERIMENT

The experiment with Mayorbela corn (fig. 1) was carried out on the same general pattern as the one just described, with the differences mentioned below. The seed were germinated in acid-alkaline washed quartz sand in wooden germinators. There were 25 cultures divided into groups of 5, each at a different boron level as follows: 0, 0.01, 0.25, 2, and 5 p.p.m. Manganese was used at the same levels as was boron. The continuous renewal method of Shive and Stahl (*6*) was used in supplying the various nutrient solutions. The experiment was harvested about 1 month after

setting the treatment differentials. Data on green and dry weight of plants were recorded and the top leaves were sectioned for chemical analyses.

ANALYTICAL METHODS

The procedure for taking the leaf samples and preparing them for chemical analyses was similar to that reported in calcium-boron studies with corn (*2*), except that for manganese determinations the corresponding aliquot portion was evaporated to dryness on a hot plate to remove excess hydrochloric acid.

The quinalizarin method of Berger and Truog was used for boron determinations (*1*). Manganese was determined according to the Saywell and Cunningham orthophenanthroline method using a Coleman spectrophotometer (*4*).

RESULTS AND DISCUSSION

TOXICITY SYMPTOMS IN SOYBEANS

One month after treatments began, soybean plants at the 0-, 0.001-, and 0.01-p.p.m. manganese levels showed better growth with less chlorosis as the boron concentration increased up to 0.5 p.p.m.

At 0 boron, increments of manganese in the substrate up to 2 p.p.m. produced better plant growth with less chlorosis. Five parts per million of manganese in the nutrient solution was definitely toxic to the plants, but the toxicity was lessened and better growth obtained with increasing concentrations of boron up to 0.5 p.p.m.

Plants receiving 0.5 p.p.m. of boron developed some necrotic spots on the lower leaves, hence this concentration appeared to be somewhat harmful. Concentrations of boron higher than this (3 and 5 p.p.m.) were definitely toxic with the appearance of necrotic spots along the leaf margins and chlorosis of the older leaves.

EFFECT OF TREATMENTS ON DRY WEIGHT OF BEANS

Table 1 presents the dry weight of beans harvested (beans plus pods). With boron absent from the substrate the maximum yield was obtained with 2 p.p.m. of manganese. With manganese absent the maximum yield was obtained with 0.5 p.p.m. of boron.

At the highest level of manganese (5 p.p.m.) yields were heaviest on plants which received intermediate quantities of boron rather than on those grown without boron, or at the two highest boron levels. This is in agreement with the previous observations made on the plants in which manganese toxicity at 5 p.p.m. was lessened and better growth obtained with increments of boron up to 0.5 p.p.m. Thus it seems that, at relatively

high concentrations of manganese in a substrate still capable of producing toxicity in plants, boron tends to prevent the detrimental effect of excess manganese on plant growth.

TOXICITY SYMPTOMS IN CORN

During the course of the experiment no definite symptoms were observed in the corn plants which could be attributed to deficient manganese in the substrate. However, slight apparent manganese toxicity developed at the two highest manganese levels (2 and 5 p.p.m.) and at the four lowest boron levels. The toxicity symptoms were characterized by the appearance of round or rectangular yellow spots, especially at the edges of leaves and extending toward the midrib or central vein. Boron-toxicity symptoms were slight in the plants at the 2-p.p.m. boron level, but were more no-

TABLE 1.—*Dry weight of soybeans (beans and pods) from plants grown in sand cultures at different boron and manganese levels*

Boron level (p.p.m.)	Yields at indicated manganese levels (p.p.m.)					
	0	0.001	0.01	0.25	2.0	5.0
	Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
0	28	33	39	42	43	23
.005	34	38	34	45	27	32
.5	44	33	43	33	44	31
3.0	26	31	35	32	27	26
5.0	22	21	16	21	19	13

ticeable in those at the 5-p.p.m. level (fig. 2). Boron-toxicity symptoms were manifested by a rather pale yellow-green color of the younger leaves and brown, dead margins and tips of the older or lower leaves. In addition, the plants were rather stunted in growth.

CHEMICAL ANALYSES OF CORN LEAVES

The results of the quantitative analyses for total and soluble boron, manganese, and iron contents of the top leaves of the corn plants are presented in table 2. It can be seen that both total and soluble boron contents are mainly determined by the boron concentration of the substrate and are largely independent of the nutrient concentration of manganese, except at the highest level of boron where total and soluble boron of the plant tissue were modified to some extent by the manganese concentrations. However, the modifications were not consistent enough to warrant a definite conclusion.

Total- and soluble-manganese contents at any given manganese level,

except the highest, were more or less independent of the boron level. At the highest manganese level (5 p.p.m.) there was a considerable reduction of both total and soluble manganese in the leaves of the corn plants as the

FIG. 2.—Corn leaf showing boron-toxicity symptoms from plants grown at a nutrient level of 5 p.p.m. boron.

boron level increased. This suggests that manganese accumulation by the plant was modified in some way as the boron concentration increased.

Although in this work no manganese determinations were made on the lower and middle leaves of plants showing toxic effects owing to a high manganese level, the fact that the apparent manganese-toxicity symptoms in the plants decreased with increments of boron in the substrate points to the possibility that boron might have acted similarly in modifying the

TABLE 2.—*Total and soluble boron, manganese, and iron of top leaves of corn plants grown at different levels of boron and manganese*

Culture No.	Treatments		Total B	Soluble B	Total Mn	Soluble Mn	Total Fe	Soluble Fe
	B	Mn						
	P.p.m.	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*
1	0	0	20.0	14.2	18.00	8.73	162.50	94.44
2	0	.01	25.0	17.8	14.00	5.98	83.75	18.97
3	0	.25	25.0	18.2	50.00	28.32	68.75	25.39
4	0	2.0	25.0	15.5	186.00	77.62	96.25	74.97
5	0	5.0	25.0	18.7	796.00	724.76	102.50	27.64
6	.01	0	20.0	10.0	16.00	7.97	70.25	18.28
7	.01	.01	25.0	13.3	14.00	1.28	75.00	32.76
8	.01	.25	25.0	18.8	58.00	40.75	90.00	37.63
9	.01	2.0	25.0	20.1	150.00	80.27	85.00	29.65
10	.01	5.0	25.0	15.7	275.00	160.37	85.00	29.41
11	.25	0	35.0	24.0	22.00	14.66	93.75	51.25
12	.25	.01	45.0	31.5	22.00	11.22	90.00	58.19
13	.25	.25	40.0	29.3	50.00	28.59	93.75	50.24
14	.25	2.0	35.0	20.7	167.00	122.07	105.00	65.66
15	.25	5.0	25.0	7.0	169.00	49.49	112.50	30.07
16	2.0	0	62.5	40.6	20.00	8.01	70.00	22.12
17	2.0	.01	62.5	45.1	14.00	8.16	75.00	37.47
18	2.0	.25	62.5	46.7	48.00	23.23	62.50	4.67
19	2.0	2.0	62.5	42.3	158.00	64.15	75.00	11.89
20	2.0	5.0	62.5	46.5	306.00	177.80	100.00	29.49
21	5.0	0	312.5	275.4	14.00	3.20	58.75	4.74
22	5.0	.01	137.5	125.5	14.00	5.28	50.00	18.07
23	5.0	.25	87.5	53.0	52.00	15.19	70.00	3.67
24	5.0	2.0	162.5	142.8	148.00	86.00	92.50	37.66
25	5.0	5.0	150.0	118.0	164.00	92.90	85.00	9.61

TABLE 3.—*Dry weight of corn (tops and roots) grown on sand culture at different boron and manganese levels*

Boron level (p.p.m.)	Yields at indicated manganese levels (p.p.m.)					
	0	0.01	0.25	2.0	5.0	Average
	Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
0	103	84	110	68	102	93
.01	95	82	91	101	115	97
.25	107	62	100	95	101	93
2.0	74	80	82	82	100	84
5.0	80	66	62	40	35	57
Average	92	75	89	77	91	

accumulation of manganese in the lower or middle leaves, as was the case in the top leaves of the corn plants.

EFFECT OF TREATMENTS ON DRY WEIGHT OF CORN

Table 3 presents data on the dry weight of both corn tops and roots. Manganese levels such as were used in the nutrient medium did not adversely affect the corn plants. However, boron concentrations of 2 p.p.m. and, especially of 5 p.p.m., reduced yields, in general.

SUMMARY

The possibilities of ameliorating manganese-induced chlorosis with boron applications were studied under greenhouse conditions using soybean and corn as indicator plants. Five levels of boron with six manganese concentrations were used in the soybean experiment. Boron and manganese were used at five levels each in the corn experiment. Observations were made as to the development of toxicity symptoms. Boron, manganese, and iron were determined in the top leaves of the corn plants. Measurements of dry-matter production were made for both crops. Five parts per million of manganese was toxic to soybean plants and reduced yields, but toxicity was lessened by increasing the boron in the nutrient solution up to 0.5 p.p.m. Boron was toxic also at levels above 0.5 p.p.m.

No definite manganese-toxicity symptoms developed in the corn plants. In general, high boron (2, 5 p.p.m.) reduced corn yields regardless of the manganese level.

Chemical analyses of the corn leaves suggests the possibility that manganese accumulation may be modified to some extent by boron concentrations.

RESUMEN

Se estudiaron bajo condiciones de invernadero las posibilidades de aliviar la clorosis inducida por manganeso con el uso de boro. Las plantas indicadoras fueron las habichuelas soyas y el maíz. En el experimento con habichuelas soyas se usaron cinco niveles de boro y seis de manganeso, mientras que en el de maíz ambos elementos se aplicaron en cinco concentraciones distintas. Se hicieron determinaciones de boro, manganeso y hierro en las hojas de maíz. Se observaron los síntomas de toxicidad y se midieron los rendimientos de materia seca en ambas cosechas. Una concentración de 5 p.p.m. de manganeso resultó tóxica para la habichuela soya reduciendo la producción de materia seca, pero la toxicidad se alivió con aplicaciones de boro hasta 0.5 p.p.m. Concentraciones de boro mayores de 0.5 p.p.m. resultaron tóxicas también.

No se observaron síntomas definidos de toxicidad atribuíbles al manga-

neso en el caso del maíz. Niveles altos (2,5 p.p.m.) de boro afectaron adversamente los rendimientos de maíz en casi todos los niveles de manganeso.

Los resultados de los análisis químicos de las hojas de maíz sugieren la posibilidad de que las acumulaciones de manganeso sean modificadas, dentro de ciertos límites, por las concentraciones de boro en el substrato.

LITERATURE CITED

1. Berger, K. C., and Truog, E., Boron determination in soils and plants using the quinalizarin reaction, *Ind. Eng. Chem., Anal. Ed.* **11** 540–45, 1939.
2. Hernández-Medina, E., and Shive, J. W., Calcium-boron relationship in the nutrition of corn and the distribution of these elements in the plant, *J. Agr. Univ. P. R.* **30** (4) 251–91, 1946.
3. Hopkins, E. F., Pagán, V., and Ramírez-Silva, F. J., Iron and manganese in relation to plant growth and its importance in Puerto Rico, *J. Agr. Univ. P. R.* **28** (2) 43–101, 1944.
4. Saywell, L. G., and Cunningham, B. B., Determination of iron-colorimetric *o*-phenanthroline method, *Ind. Eng. Chem.*, **9** 67–9, 1937.
5. Schapelle, N. A., The effect of pH and of certain minor elements on the growth of pineapples in water cultures, *J. Agr. Univ. P. R.* **26** (3) 63–72, 1942.
6. Shive, J. W., and Stahl, A. L., Constant rate of continuous solution renewal for plants in water cultures, *Bot. Gaz.* **84** 317–23, 1927.

Optimum Weights to Which Pigs Should Be Carried in Puerto Rico for Maximum Profits

Ismael Carlo[1]

INTRODUCTION

The importance of the swine industry in Puerto Rico has been increasing rapidly in the past few years. New and bigger swine herds have been established in the Island and several farmers are substituting garbage for concentrate feeding. A few farmers are already buying the ingredients and mixing their own rations on their farms. Tables of optimum weight to which pigs should be carried for maximum profit should be valuable as a guide for all swine producers in the Island.

Although tables of this kind were prepared for Durocs and Native pigs in 1949 (*1*)[2], it was felt that, with more data available, their revision was necessary. At the same time a table was needed for the crossbred pigs developed at this Station.

METHODS

The tables presented herein were prepared on the basis of data collected from 18 Duroc Jersey barrows and 73 Landrace Large Black Duroc crossbred barrows and are given separately.

The pigs considered in this study entered feeding trials which extended from weaning, at 56 to 182 days of age. The feed consumed and the gain in weight of the pigs was recorded every 14 days. The data were obtained from eight feeding trials covering the period from 1951 to 1957.

The feed used in all these trials consisted of concentrated rations mixed at the experimental farm at Lajas Substation with approximately 15.0-percent crude-protein content, 3.0 percent of fat, and 6.5 of fiber.

The data collected were plotted as growth curves in a graph. The maximum weights for optimum profit were calculated by the method of González Chapel and Cabrera (*1*)[2]. This was based on the liveweight of hogs selling at from 15 to 31 cents a pound, with feed costs varying from $3.00

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[2] Italic numbers in parentheses refer to Literature Cited, p. 37.

TABLE 1.—*Optimum weights for maximum profits in Duroc Jersey barrows at per pound selling price of hogs (liveweight) indicated*[1]

Feed cost per 100 lb.	$0.15		$0.17		$0.19		$0.21		$0.23		$0.25		$0.27		$0.29		$0.31	
	F	W	F	W	F	W	F	W	F	W	F	W	F	W	F	W	F	W
3.00	380	123	519	149	642	170	753	186	854	200	946	212	1,031	222	1,111	230	1,184	238
3.25	291	105	430	133	553	155	664	173	790	192	857	201	943	211	1,022	221	1,096	229
3.50	209	86	348	117	471	141	582	160	683	176	775	190	861	201	940	211	1,013	220
3.75	132	68	271	100	395	126	505	147	606	164	699	179	784	191	863	202	937	211
4.00	61	49	200	84	323	111	459	138	535	152	627	168	712	181	792	192	866	202
4.25	—	—	132	68	256	97	367	116	467	140	560	156	645	170	724	182	798	193
4.50	—	—	69	51	192	82	303	107	404	128	497	145	582	160	661	173	735	184
4.75	—	—	9	35	132	68	243	94	344	116	437	134	522	150	601	163	675	175
5.00	—	—	—	—	76	53	187	81	287	104	380	123	465	140	544	154	618	166
5.25	—	—	—	—	21	39	132	68	233	92	326	112	411	129	490	144	564	157
5.50	—	—	—	—	—	—	81	54	182	80	274	101	360	119	439	134	513	148

[1] F = feed consumed to reach optimum weight; W = weight of the animal for maximum profit. Pigs should not be raised under conditions designated by the use of dashes.

TABLE 2.—*Optimum weights for maximum profits in Landrace Duroc barrows at per pound selling price of hogs (liveweight) indicated*[1]

Feed cost per 100 lb.	$0.15		$0.17		$0.19		$0.21		$0.23		$0.25		$0.27		$0.29		$0.31	
	F	W	F	W	F	W	F	W	F	W	F	W	F	W	F	W	F	W
3.00	392	120	567	153	722	179	862	200	990	217	1,106	232	1,214	242	1,314	252	1,407	264
3.25	280	96	455	132	611	160	750	183	878	202	994	217	1,102	231	1,202	243	1,295	253
3.50	176	73	351	112	507	142	647	166	774	187	891	204	1,031	222	1,098	231	1,224	245
3.75	79	50	255	91	410	123	550	150	678	171	794	190	934	210	1,002	219	1,128	234
4.00	—	—	164	70	320	105	460	133	582	156	704	176	812	192	912	207	1,005	219
4.25	—	—	79	50	235	87	375	116	502	141	619	162	727	179	827	195	920	208
4.50	—	—	—	—	155	68	295	100	422	126	539	148	647	166	747	182	840	196
4.75	—	—	—	—	79	50	220	83	347	111	464	134	571	153	672	170	765	185
5.00	—	—	—	—	8	31	148	66	275	95	392	120	499	141	599	158	693	174
5.25	—	—	—	—	—	—	79	50	207	80	323	106	431	128	531	146	624	263
5.50	—	—	—	—	—	—	15	19	142	65	258	92	366	115	466	134	559	151

[1] F = feed consumed to reach optimum weight; W = weight of the animal for maximum profit. Pigs should not be raised under conditions designated by use of dashes.

to $5.50 per 100 pounds. Overhead cost was not considered in the calculations. These costs vary greatly from farm to farm according to the management procedures followed. Obviously the smaller the overhead costs the larger the net profits.

THE TABLES

The way to use tables 1 and 2 can be demonstrated by figuring a hypothetical situation in which feed price is $4 per 100 pounds and the pigs are selling at $0.25 per pound liveweight. For the Duroc barrows table 2 shows that under these conditions the optimum weight to which to carry the hogs would be 168 pounds. To attain that weight the pigs will have consumed 627 pounds of feed. The feed cost would be $25.08 and the total selling price of each pig $42, with a profit over the feed cost of $16.92 per head.

SUMMARY

A study on the feeding of swine at the Lajas Experiment Substation shows the maximum weights that animals of the Duroc Jersey and Landrace X Duroc breeds should reach for best yield and maximum profit. Pigs considered in this study entered feeding trials which extended from weaning at 56 days to 182 days of age. Feed consumed and gain in weight of the pigs was recorded every 14 days. Reference tables included were worked out on this basis.

RESUMEN

El presente trabajo incluye información sobre un estudio llevado a cabo en la Subestación Experimental Agrícola en Lajas para determinar los pesos máximos a que se deben engordar los cerdos de las razas Duroc Jersey y Landrace X Duroc, de modo que la crianza de estos animales produzca los rendimientos mayores.

En los experimentos de alimentación se usaron cerdos desde la edad del destete (56 días) hasta que tuvieron 182 días de nacidos. Cada 14 días se anotaban las cantidades de alimentos consumidos, como también las ganancias en peso. Sobre esta base fué que se prepararon las tablas incluídas, de las cuales se puede deducir que bajo las condiciones de estos experimentos, el peso máximo a que se engordó un cerdo de la raza Duroc Jersey fué de 168 libras. Para llegar a este peso el animal consumió 625 libras de alimento con un valor de $25.08. El precio de venta de este cerdo fué de $42.00 según los precios que prevalecieron durante los experimentos y la ganancia alcanzó a $16.92 por cabeza.

LITERATURE CITED

1. González Chapel, A., and Cabrera, J. I., Cross-breeding for swine production in Puerto Rico, *J. Agr. Univ. P. R.* **33** (4) 119–55, 1949.

AGRICULTURAL EXPERIMENT STATION

(*Continued from inside front cover*)

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